METHOD FOR FORMING CONTACT PLUG HAVING DOUBLE DOPING DISTRIBUTION IN SEMICONDUCTOR DEVICE

Field of the Invention

The present invention relates to a semiconductor device; and, more particularly, to a method for forming a contact plug in a semiconductor device.

Description of Related Arts

In a cell region of a dynamic random access memory (DRAM) device, a contact for making a connection between a pn junction of a substrate and a capacitor or between a pn junction of a substrate and a bit line, that is, a cell plug is generally made of a polysilicon layer.

In the cell plug (hereinafter referred as to polysilicon plug) using such polysilicon layer, an n-type dopant with a concentration greater than 1×10^{20} dopants/cm^3 is used to increase electric conductivity. Phosphorous (P) is a commonly used n-type dopant.

Fig. 1 is a cross-sectional view showing a semiconductor device having a conventional contact plug structure.

As shown, each gate line including a gate oxide layer 12, a gate electrode 13 and a hard mask 14 sequentially stacked on a substrate 11 is spaced apart from each other with a predetermined distance, whereby a number of the gate lines are

formed. An insulating spacer 15 is subsequently formed at lateral sides of the gate line.

A contact isolation layer 16 for insulating and isolating neighboring plugs fills a space between the gate lines as exposing the substrate 11. A polysilicon plug 17 is buried into a space between the gate lines provided by the contact isolation layer 16.

In Fig. 1, the polysilicon plug 17, which is a contact plug, is deposited through the use of a low pressure chemical vapor deposition (LPCVD) technique. Also, such gas as SiH_4, SiH_2Cl_2 and the like is used while proceeding the above deposition procedure at a temperature ranging from about 500 °C to about 600 °C. Concurrently, an n-type dopant, e.g., P, is doped by using PH_3 gas.

A polysilicon germanium plug is also used as a contact plug. At this time, such gas as GeH_4, GeH_2Cl_2 or Ge_2H_6 is added to the SiH_4, SiH_2Cl_2 and the like.

As described in the above, PH_3 gas is used to dope P in accordance with the prior art. As a flow quantity of the PH_3 gas increases, a concentration of P within the polysilicon plug 17 also increases. Conversely, the concentration of P decreases in case of decreasing the flow quantity of the PH_3 gas. Generally, the concentration of P within the polysilicon plug 17 is maintained consistently above 1×10^{20} dopants/cm^3 throughout the whole thickness. The reason for maintaining this high concentration is to increase electric conductivity of the polysilicon plug 17.

Fig. 2 is a graph showing a doping distribution of P with respect to a thickness of the polysilicon plug illustrated in Fig. 1.

As shown, a doping concentration of P within the polysilicon plug consistently maintains a high concentration C although a thickness T of the polysilicon plug increases.

However, as a device size becomes increasingly smaller, it is also increasingly necessary to form a shallow junction. Therefore, there occur diffusions of P into a substrate while proceeding a thermal process after forming the polysilicon plug.

Accordingly, it is necessary to decrease the doping concentration of P within the polysilicon plug as simultaneously as to decrease a temperature and operation time of the thermal process in order to suppress the diffusions of P.

However, in case of uniformly decreasing the doping concentration of P within the whole polysilicon plug, electric conductivity of the polysilicon plug is also decreased, further resulting in an increase of the polysilicon plug resistance. Eventually, device properties are degraded.

Summary of the Invention

It is, therefore, an object of the present invention to

provide a method for forming a contact plug in a semiconductor device capable of suppressing diffusions of dopants implanted into a contact as simultaneously as of preventing an increase of contact resistance.

In accordance with an aspect of the present invention, there is provided a method for forming a contact plug in a semiconductor device, including the steps of: forming a contact isolation layer on a substrate, the contact isolation layer having an opening exposing a partial portion of the substrate; depositing a conductive layer within the opening of the contact isolation layer; doping dopants in a manner to allow the conductive layer to have different doping distributions with respect to a thickness; and forming a contact plug within the opening through a planarization process applied to the conductive layer.

Brief Description of the Drawing(s)

The above and other objects and features of the present invention will become apparent from the following description of the preferred embodiments given in conjunction with the accompanying drawings, in which:

Fig. 1 is a prospective view illustrating a cell plug structure of a conventional semiconductor device;

Fig. 2 is a graph showing a relationship between a doping concentration distribution and a thickness of the polysilicon plug illustrated in Fig. 1;

Fig. 3 is a flowchart showing procedures of a method for forming a contact plug in a semiconductor device in accordance with a preferred embodiment of the present invention;

Fig. 4 is a flowchart showing procedures of implanting dopants in detail described in Fig. 3;

Fig. 5 is a graph showing a relationship between a dopant concentration distribution and a thickness of the contact plug described in Fig. 3; and

Figs. 6A to 6C are prospective views showing a method for forming a polysilicon plug in accordance with the procedures described in Fig. 3.

Detailed Description of the Invention

Fig. 3 is a flowchart showing procedures of a method for forming a contact plug in a semiconductor device in accordance with a preferred embodiment of the present invention. Also, Fig. 4 is a flowchart showing detailed procedures for implanting dopants described in Fig. 3. Fig. 5 is a graph showing a relationship between a dopant concentration distribution and a thickness of the contact plug described in Fig. 3.

Referring to Fig. 3, the method for forming a contact plug in a semiconductor device includes a series of the steps as the following: they are, a gate line formation 21, an insulating spacer formation 22, a contact isolation layer formation 23, a conductive layer deposition 24 within an

opening provided by the contact isolation layer, an implantation 25 of dopants having different distributions with respect to a thickness of the conductive layer and a contact plug formation 26 through planarization of the conductive layer.

Referring to Figs. 4 and 5, the implantation of the dopants further includes: a first doping procedure 25A wherein dopants are doped until reaching a second concentration C by gradually increasing a doping concentration from a first concentration C_0 to a second concentration C for an interval between an initial conductive layer deposition thickness T_0 and a target deposition thickness T_1; and a second doping procedure 25B wherein the dopants are doped with a uniform concentration allowing the second concentration C to be consistently maintained for an interval from the target deposition thickness T_1 to a complete deposition thickness T_2.

To maintain a difference between the first and the second concentrations C_0 and C, a flow quantity of a doping gas used in the first doping procedure 25A is less than that of the doping gas used in the second doping procedure 25B. The flow quantity is gradually increased until the doping concentration reaches to the second concentration C from the first concentration C_0.

On the other hand, a flow quantity of the doping gas used in the second doping procedure 25B is larger than that of the doping gas used in the first doping procedure 25B. Also, the doping concentration is maintained consistent in order to

maintain the second concentration C.

Meanwhile, the conductive layer deposition procedure 24 is proceeded by using a low pressure chemical vapor deposition (LPCVD) technique. That is, a polysilicon layer or a polysilicon germanium layer is deposited at a temperature ranging from about 500 °C to about 600 °C. At this time, the target deposition thickness T_1 preferably ranges from about 500 Å to about 1000 Å if the complete deposition thickness T_2 of the conductive layer is assumed to be in a range from about 3000 Å to about 3500 Å.

Also, the first concentration C_0 ranges from about 5×10^{18} dopants/cm^3 to about 1×10^{20} dopants/cm^3, while the second concentration C ranges from about 1×10^{20} dopants/cm^3 to about 3×10^{20} dopants/cm^3. Herein, the first and the second concentrations C_0 and C are sufficient to increase electric conductivity of the contact plug.

PH_3 gas is used as the doping gas for implanting the dopants.

Figs. 6A to 6C are prospective views showing a method for forming the polysilicon plug described in Fig. 3.

Referring to Fig. 6A, each gate line including a gate oxide layer 32, a gate electrode 33 and a hard mask 34 sequentially deposited on a substrate 31 is spaced apart from each other with a predetermined distance, whereby a number of the gate lines are formed.

Next, an insulating spacer 35 is formed at lateral sides of the gate line. Particularly, the insulating spacer 35 is

formed through an etch-back process performed after depositing an oxide layer or a nitride layer on an entire surface including the gate line.

Subsequently, an inter-layer insulating layer is formed on an upper part of the substrate 31 where the insulating spacer 35 is formed. A planarization process is performed until exposing a surface of the hard mask 34 is exposed. The inter-layer insulating layer is then etched with use of a contact mask so to form a contact isolation layer 36.

Therefore, a first polysilicon layer 37A is deposited on an opening between the gate lines provided by the contact isolation layer 36, e.g., an entire surface including a contact hole by employing a LPCVD technique. This deposition continues until reaching a target deposition thickness T_1 as a concentration of implanted dopants gradually increases from the first concentration C_0 to the second concentration C.

At this time, the first polysilicon layer 37A deposition is proceeded at a temperature ranging from about 500 °C to about 600 °C by using such gas as SiH_4, SiH_2Cl_2 and so on. Particularly, P is doped with use of PH_3 gas, and a concentration of the P gradually increases until reaching a target deposition thickness T_1 from an initial deposition thickness T_0.

That is, the concentration increases from the first concentration C_0 to the second concentration C until reaching the target deposition thickness T_1 from the substrate 31 contacting to the first polysilicon layer 37A. At this time,

the first concentration C_0 ranges from about 5×10^{18} dopants/cm^3 to about 1×10^{20} dopants/cm^3, while the second concentration C ranges from about 1×10^{20} dopants/cm^3 to about 3×10^{20} dopants/cm^3.

For instance, in case that the complete deposition thickness T_2 of the polysilicon layer, i.e., the contact plug, ranges from about 3000 Å to about 3500 Å, the first polysilicon layer 37A is deposited to a thickness of about 500 Å to about 1000 Å. Also, a low quantity of the doping gas, i.e., PH_3, is added during the first polysilicon layer 37A deposition so as to reach the first concentration C_0, and then, the PH_3 is increasingly added so that the doping concentration within the first polysilicon layer 37A becomes the second concentration C.

Referring to Fig. 6B, after completing the first polysilicon layer 37A deposition, a second polysilicon layer 37B is deposited until reaching the complete deposition thickness T_2. At this time, the first and the second polysilicon layers 37A and 37B are deposited under an in-situ environment by using a LPCVD technique. The reason for classifying the polysilicon layer into the first and the second polysilicon layers 37A and 37B is to show deposition procedures according to flow quantity changes in the doping gas so that there result in different doping concentrations of P for the first concentration C_0 and the second concentration C.

Hence, once the doping concentration of P implanted into

the first polysilicon layer 37A reaches to the second concentration C, the second polysilicon layer 37B is deposited until having the complete deposition thickness T_2. At this time, the flow quantity of the PH_3 gas does not change in order to maintain the second concentration C consistent until reaching to the complete deposition thickness T_2.

Eventually, compared to the first polysilicon layer 37A deposition, a high flow quantity of the PH_3 gas is consistently added during the second polysilicon layer 37B deposition so that the doping concentration of P is maintained consistently to be the second concentration C within the second polysilicon layer 37B. At this time, the flow quantity of PH_3 gas is remained the same quantity added to reach the second concentration C from the first concentration C_0 used for obtaining the target deposition thickness T_1. Herein, the second concentration C ranges from about 1×10^{20} dopants/cm^3 to about 3×10^{20} dopants/cm^3.

Referring to Fig. 6C, the first and the second polysilicon layers 37A and 37B are proceeded with a chemical mechanical polishing (CMP) process or an etch-back process so as to form a polysilicon plug 37 wherein a surface of the opening is planarized.

The polysilicon plug 37 is classified into the first polysilicon layer 37A having a incremental concentration distribution wherein a low concentration of P gradually increases and the second polysilicon layer 37B having a uniform concentration distribution wherein a high

concentration of P is added and consistently maintained throughout. That is, the polysilicon plug 37 has a double doping distribution.

It is possible to minimize diffusions of P during a subsequent thermal process by forming the polysilicon plug 37 having the double doping distribution. Simultaneously, it is also possible to prevent an increase in resistance of the polysilicon plug 37. In other words, the P does not diffuse into parts to which the high concentration of P is added but only into parts proximate to the substrate 31 during the thermal process. As a result, it is possible to prevent an increase of contact resistance by minimizing a decrease of the doping concentration of P.

Although Figs. 6A to 6C provide the preferred embodiment using the polysilicon plug, it is still possible to form a double doping distribution using polysilicon germanium as the contact plug. Compared to the polysilicon plug, this substitution provides an effect of further decreasing the resistance based on the known fact that the polysilicon germanium has the resistance lower than the polysilicon.

By following the preferred embodiment of the present invention, it is possible to improve a degree of integration through the realization of a cell plug process capable of suppressing diffusions of P and providing a low resistance.

While the present invention has been described with respect to certain preferred embodiments, it will be apparent to those skilled in the art that various changes and

modifications may be made without departing from the scope of the invention as defined in the following claims.